Challenges to Collaborative Tool Adoption in a Manufacturing Engineering Setting: A Case Study

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Abstract

This study examined a collaborative tool intervention within a geographically-distributed, engineering-design team in a large manufacturing company. Baseline data collection to determine user requirements was followed by deployment of collaborative tools and subsequent data collection to assess the impact of the collaborative tools on team processes. A small proportion (1/3) of the team adopted the introduced collaborative tools, and that tool use had a positive impact on collaborative work. Findings from this study suggest that collaborative tools must be clearly superior to existing practices to merit the effort of deployment, adoption, and subsequent use, since the burden of learning and mastering a new tool in a corporate environment may not outweigh the perceived benefits.

1. Introduction

As American industry continues to meet the challenges of global competition, rapid change and increasing complexity, organizations have dramatically increased the number of employees working in geographically-distributed teams [5, 15, 23]. Distributed teams are important to a global organization's success because they allow knowledge to be shared across organizational boundaries and aid in the creation of new products and services [17, 19]. Furthermore, having the option of forming geographically-distributed teams offers organizations greater flexibility [24].

Specifically, globalization of manufacturing has created a growing need for product development to occur among distributed teams, driving the use of collaborative tools [28]. Collaborative product development is the process of sharing information in the design and creation of products to speed time-to-market [14] and to provide the targeted market's contextual requirements, especially for consumer products [3]. Designers, engineers, and managers must make decisions based on analysis from shared data from many sources. In fact, today's product development efforts are dominated by communication, teamwork, coordination, meetings, negotiation, and conflict management [31].

While geographically-dispersed teams may seem an attractive solution to global organizations, these teams face numerous challenges to effective performance, including coordination and communication barriers. For instance, distributed teams using computer-mediated communication may take longer to complete tasks than face-to-face teams [2, 4, 12, 20]. In addition, they may be less effective and more frustrated in trying to accomplish the higher-level decision-making tasks often required of design engineers [29].

While there are many technologies to facilitate distributed work, their impact on the performance of distributed teams in manufacturing, engineering settings has not been examined systematically. Our research objective was to assess the impact of collaborative tools on a geographically-distributed, product-design team. Our approach was to use empirical measurement to assess the collaboration needs of the design team. We then deployed available applications, and subsequently collected empirical data to assess the impact of the collaboration tool implementation.

2. Facilitating collaboration in distributed teams

Distributed teams need a combination of communication mechanisms to adequately exchange information among team members [1]. In general, distributed teams often rely on technology-supported communications, such as telephones, electronic mail (email), and video conferencing, more than face-to-face communications to accomplish their work [16, 17]. Email has historically played a role in allowing virtual teams to share information, coordinate work, and sustain and create its identity in the absence of a physical setting [1, 7]. As such, it is an invaluable tool for supporting asynchronous group activities.

However, Olson and Olson [25] depict group work as a combination of synchronous and asynchronous activities, where individuals move between individual tasks, coordination, and real time clarification of goals. They suggest that groups face a challenge in making the transition between synchronous and asynchronous activities. Collocated groups may find cumbersome means of dealing with this problem (e.g., expecting workers to always be at their desks and therefore immediately accessible), and virtual teams face the same difficulty with the added feature of remote team members.

Several existing technologies facilitate collaborative product development by supporting synchronous and asynchronous communication, scheduling, planning, task management, document and application sharing, and desktop conferencing [13, 26, 32]. Olson and Olson [25] suggest that awareness tools in particular support this transition by allowing team members access to other individuals in order to coordinate real-time interactions. Instant messenger services (e.g., ICQ[1&2]) and online calendars (e.g., Microsoft Outlook) provide awareness, and in the latter case, facilitate scheduling meetings.

Where email is used for asynchronous coordination, and awareness tools are used to aid teams in the transition between synchronous and asynchronous work, desktop conferencing enables synchronous communication to be enhanced by data or application sharing. Desktop conferencing tools (e.g., NetMeeting) allow geographically-distributed teams to communicate and share information as though they were collocated [18]. For example, previous studies have found that desktop conferencing is helpful for groups with text-based tasks and graphical information needs - particularly where two or more collaborators need to maintain a shared orientation, or common ground [22, 33].

2.1. Expectations for collaboration tool use in the research site

Thus, we found support in the literature for several types of collaboration tools (email, electronic calendar, awareness tools, desktop conferencing) to enhance the functioning of our case study team. Our goal was to assess the needs of the team and suggest tools targeted to their specific needs. That said, we held several expectations regarding which tools the team might find useful, and how these tools might affect the team's functioning.

For instance, because product development teams involve workers from different countries that can span multiple time zones [3], we expected the team to face coordination difficulties. With little synchronous time, this type of virtual team has increased coordination needs for interdependent work [24], and often depends on a combination of synchronous and asynchronous means of coordination. Specifically, when work hours overlap minimally, team members may need to wait in order to obtain information and therefore, complete tasks. Thus, we expected that the distributed team members in our study would encounter difficulties in coordinating work with their remote counterparts, and would be interested in adopting awareness tools. In addition, we expected that coordination among team members should improve following the implementation of awareness tools.

Second, while many distributed teams may benefit from desktop conferencing tools, we expected that this type of tool might be particularly helpful for design engineers involved in collaborative product development. Studies of engineers suggest that a heavy reliance on visual and graphic material underlies the basic functioning of design engineering. Henderson [5] describes the visual culture of engineering as one where co-workers communicate ideas via sketches, and often need to refer to drawings and designs to accomplish their work. We therefore expected that this team would be interested in a desktop- conferencing tool, to visually enhance their synchronous activities. We expected that implementing such a tool in this team should enhance their collaborative processes and team performance.

2.2. Evaluating the impact of collaboration tools in the product design team

The goal of this study was to implement collaboration tools to aid a distributed, product-design team. Thus, the outcomes we were interested in measuring were adoption of collaboration tools, and team functioning or performance following collaboration tool implementation.

A key issue in studying technology use in business settings is assessing the impact it has on performance and process [18], yet a common difficulty encountered by researchers is gaining access to measures of team and individual performance. Furthermore, Ahuja and Carley [1] argue that in virtual organizations, a focus on organizational outcomes may be misleading, by not taking collaborative outcomes into account. Since our team crossed several divisional boundaries and included multiple subteams with overlapping membership, we considered divisional and project team goal attainment an inadequate measure of performance.

Instead, we chose to assess the team's functioning in terms of coordination, as it is a means to understanding the performance of distributed teams. For instance,

1. Any commercial product identified in this document is for the purpose of describing a collaborative software environment. This identification does not imply any recommendation or endorsement by NIST.
2. http://www.icq.com/

Herbsleb and Grinter [6] found that difficulties in coordination, such as knowing whom to contact for what, lead to serious problems in team members accomplishing their work. Furthermore, Herbsleb et al [11] found that the most frequent consequence of cross-site coordination problems was delay in resolving task-related problems, such as design errors. They explained that work issues that might be resolved quickly in a collocated setting were sometimes delayed by days or weeks as distributed team members tried to establish contact with one another. Following from this research, we believed that coordination and delay were appropriate surrogate measures of performance for distributed teams. Furthermore, we expected that such coordination and delay difficulties should decrease with collaborative tool use.

3. Method

3.1. The Research site

The research site was an US-based, automobile parts manufacturing company with over $2.7 billion in global sales in 1999. At the time of our study, the company, which we will refer to as "Auto 1," had over 14,000 employees at 60 locations in 13 countries. Auto 1 sold their products to major automobile and truck manufacturers in North America, Europe, and Asia. Auto 1 management approached us to volunteer a new design team as subjects for our research. The team had responsibility to bring an innovative automotive system to market, with anticipated sales of over $1 billion. The catch, and the driver for collaboration technology use, was that development of the new system would require a successful union of expertise among previously disparate business units within Auto 1. These business units were working together for the first time across multiple time zones, addressing cultural differences, political and organizational challenges, and heterogeneous information technology capabilities. Auto 1 managers believed that the team would require the help of collaboration technologies to succeed, and they also felt that this team would be used to determine the value of subsequent cross-business, product-development programs. Thus, Auto 1 management embraced collaborative product development and the tools to support it.

3.2. The product and team

The team identified by Auto 1 managers was a product-development group of approximately 50 employees. The team comprised several distributed sub-teams involved in a single project. To protect their anonymity, we will refer to the team as the CAR team.

One reason this team was selected was because it was early enough in the production process to remain intact throughout the life of our study (one year). When we began the study, the project was in the concept stage. During the course of our year-long investigation, the project progressed into the product-intent stage, and then moved to the product-release stage at the conclusion of our study.

This highly functioning team was ready to adopt new technology, yet it faced numerous potential challenges to collaboration inherent in its work structure. For instance, the design, development, test, and manufacture of the team's product involved integration of many components, requiring collaboration among team members in four countries, many of whom had never worked together and were not used to the unique, cross-divisional, global arrangement. Engineers, designers, and managers were required to share a variety of data types within the dispersed team, including design data from different CAD applications, prototype test data, design analysis data, and manufacturing specifications.

3.3. User-centered design and data collection

We used a web-based baseline survey of the distributed team members to assess the potential utility of collaborative tools that might be introduced to the team, and measure of team communication, coordination and performance. All 51 members of the team were invited via email to participate in the study and to complete the baseline survey. No incentives for participating in the study were offered. Thirty-four out of 51 (67%) employees completed the pre-intervention survey from 6 geographically distributed sites, in 3 countries. Most respondents (65%) came from European sites. Respondents were predominantly (97%) male, 35 years old (s.d. = 8.46), with typical organizational tenure of 6.4 years (s.d. = 8.91). After the introduction of collaborative tools, a follow-up survey was administered to the entire team, which had grown to 61 members. 34 participants (56% of the team) responded. 38% of these respondents had also completed the pre-intervention survey. Similar to the initial survey, 68% of respondents were located in Europe and 32% were located in offices in the United States.

In addition, we conducted interviews with a subset of the team members to plan further implementation and support of the teams' collaborative needs. Twenty-four semi-structured interviews were conducted, 10 in one site in North America, 16 at one site in Germany and 3 via telephone to Australia. Participants were selected to represent a variety of positions in the team and distributed work needs. These included managers, engineers, and technicians; potential early adopters and those less interested in new tools; and individuals in moderate and intense distributed work arrangements. The interviews ranged from 20 - 40 minutes. The interviews with the team members and management addressed work role and background, identification of local and remote collaborators, the current means of communicating with remote collaborators, and tools, obstacles and opportunities for remote collaboration.

3.4. Survey Measures

We collected background information to determine the participants' age, gender, tenure in the organization, and office location. This information was used primarily to characterize the research site and control for extraneous influences on our statistical analyses [27]. In addition, we collected information on work processes such as communication patterns across different media, to assess the team's collaboration practices and needs.

We measured CAR team members' receptivity to new collaboration tools with 3 items (on a 10 point scale) regarding their motivation to adopt an electronic calendar, availability and presence tools, and a shared, mark-up tool. These items have been used diagnostically in other similar studies [e.g., 30]. In the follow-up survey we were interested in documenting which tools the team had actually used. Thus, we asked participants (with 3 items, on a 10 point scale) to indicate how often they had used an electronic calendar (MS Outlook), a presence awareness tool (ICQ), and a desktop conferencing tool (NetMeeting) in the last six months. In addition, we assessed the impact of the desktop conferencing tool deployment with 4 items. We asked if desktop conferencing changed the manufacturing design process, and if so, to what extent it had improved the quality, efficiency and speed of the design process (on a 7 point scale). The three items (on a 7 point scale) assessing coordination were derived from Herbsleb and Grinter's [10] study. The two items assessing performance were derived from Herbsleb et al’s [11] study, and asked participants to determine frequency and length of delays in work as a result of task-related difficulties. Participants rated local and remote co-workers in the CAR team separately for coordination and performance items

4. Collaboration requirements and collaborative tool deployment

4.1. Baseline analysis

We performed qualitative analyses to determine the most frequently mentioned issues in distributed work arising from the interview data. To accomplish this we followed standard practices for qualitative data analysis [21, 8]. We constructed inductive code categories first by reading through the background interviews and creating an extensive list of all the issues mentioned. We subsequently clustered these into themes of related statements. We used the most frequently mentioned strategic themes to summarize the current practices and barriers in distributed work for the CAR team. We used descriptive statistics from the baseline survey to support our themes and to aid in recommending collaborative tool interventions within the CAR team. We found that the data fell into three themes: Heavy reliance on email, maximizing synchronous time, and coordination issues.

4.2. Collaboration requirements

4.2.1. Heavy reliance on email. To overcome the coordination issues inherent in remote collaboration, team members established norms to help them expedite their work. While these norms were resourceful adjustments to dispersed teamwork, they were cumbersome solutions for collaborative work problems. Specifically, team members described using email foremost as a tool for contacting remote team members. Email was used as the primary means for exchanging task requests, data, reports, designs and sketches. It was perceived as ubiquitous at the desktop, reliable, and well-understood.

Yet, these norms fell short of the respondents' needs. Team members encountered difficulties in exchanging email while traveling. Furthermore, participants described file transfer as sometimes slow and causing delays in work. File transfer was especially slow due to large file sizes (often CAD drawings), and because of incompatibilities in encryption standards, leading to cumbersome security procedures (using ftp, zipped files and passwords).

Finally, email did not offer a rich medium for information exchange. For instance, email did not easily allow users to identify or describe visual details, which are common in design work. As one participant explained:

It is difficult to discuss details over email. Unnamed components must be described to identify them to others, (like the second bow in the tube) since not all parts have names. It's very difficult to discuss this over email because communication is difficult and slow.

4.2.2. Maximizing synchronous time. One of the challenges facing teams distributed across multiple time zones is the scarcity of overlapping work times. CAR team members mentioned commonly using the telephone for synchronous work. This was supported by findings that participants used the telephone about 13 times per week (m = 13.2, s.d. = 16.19) for work communication, with 29% of respondents reporting high telephone use (21 or more times per week). A few team members typically used desktop conferencing tools (m = 1.83, s.d. = 5.2, times per week and 3% reporting 21 or more instance of desktop conferencing per week), and fewer still used video conferencing (m = .47, s.d. = 1.1, with no high use). Often, team members coordinated the scheduling of synchronous meetings via email. For example, one participant mentioned that one "may say (over email) 'call me this afternoon, I have to talk to you about such and such.'"

Typically, team members conducted meetings via the telephone in order to discuss coordination issues, plans, acquiring further information or details, and clarifying issues mentioned in email. Team members mentioned that they would like to use visual aids to enhance such meetings. Some team members sent faxes to exchange sketches or other materials simply and quickly. In addition, team members who discussed sketches, designs or other visual material, expressed the desire to have tools to improve mutual understanding of the material (such as being able to simultaneously point to problem areas).

4.2.3. Coordination issues. In general, respondents described experiencing frustration due to limited synchronous time they shared with co-workers in other time zones, difficulty in coordinating among multiple time zones (such as Europe, US and Australia), and delays in work. One participant expressed this problem as follows, saying: "...the very different time zones are the biggest problem [in collaboration]. It is nearly impossible to have all three continents on the phone at the same time. Most (of our) employees are used to the North America - Europe time difference. Australia is more difficult."

On average, team members reported 4 delays each month, with 90% encountering delays of a day or more when working with remote collaborators. Furthermore, team members described difficulty in scheduling common meeting times with both local and remote co-workers. Interview data suggested that problems in scheduling stemmed from difficulty locating local co-workers who traveled frequently. In general, problems in locating and scheduling were more pronounced with remote than local co-workers (refer to Table 1). Furthermore, coordination issues were related to delays in work. For instance, scheduling difficulty with remote co-workers was significantly correlated ($r = .44$, and $r = .53$, $p < .01$) with number and length of delays in work due to remote co-workers, and difficulty locating remote co-workers was significantly correlated with frequency of delay ($r = .59$, $p<.01$).

4.3. Collaboration tool selection and deployment

The baseline analysis found that while team members were often using email effectively for asynchronous work, it served as a barrier for synchronous work. We suggested implementing a desktop conferencing tool to minimize the delay of document exchange in synchronous time. Because of cost and availability within Auto 1, and

Table 1: Coordination and delay variables correlated with one another.

Variables	1	2	3	4	5	6	7	8
1. Scheduling difficulties (local co-workers)	- - -							
2. Scheduling difficulties (remote co-workers)	$.61^{5**}$	- - -						
3. Difficulty finding local co-workers	$.65^{2**}$	$.59^{5**}$	- - -					
4. Difficulty finding remote co-workers	$.62^{6**}$	$.58^{6**}$	$.79^{6**}$	- - -				
5. Frequency of delay (local co-workers)	$.34^{7}$	$.08^{9}$	$.21^{7}$	$.15^{10}$	- - -			
6. Frequency of delay (remote co-workers)	$.34^{8}$	$.44^{8*}$	$.36^{8}$	$.56^{9**}$	$.31^{8}$	- - -		
7. Length of delay due to local co-workers	$.29^{8}$	$.29^{10}$	$.27^{8}$	$.30^{11}$	$.32^{8}$	$-.05^{10}$	- - -	
8. Length of delay due to remote co-workers	$.19^{12}$	$.53^{12*}$	$.25^{12}$	$.46^{13}$	$.06^{12}$	$-.41^{11}$	$.4^{12}$	- - -

Note. The statistic reported here is Pearson's r. The superscript * symbol indicates the level of significance of the correlation, and the superscript numbers indicate the sample size. Legend: *Correlation is significant at the 0.05 level (2-tailed). ** Correlation is significant at the 0.01 level (2-tailed). 1.n = 29, 2. n = 28, 3. n = 27, 4. n = 26, 5. n = 25, 6. n = 24, 7. n = 23, 8. n = 22, 9. n = 21, 10. n = 20, 11.n = 19, 12.n = 18, 13.n = 17.

because of prior favorable experiences, CAR management selected Microsoft NetMeeting as their desktop conferencing application.

To improve both synchronous and asynchronous coordination, we suggested that awareness tools (such as instant messaging) and calendaring applications would be useful in helping distributed team members find one another and schedule meetings. A subset of team members were already using Microsoft Outlook for calendaring at Time 1, and this tool was supported within the company. In addition, we suggested that a presence awareness tool could help participants target their telephone calls to times they knew their distributed colleagues were available.

Initially, the Auto 1 management team agreed to the implementation of this full range of collaborative tools. Ultimately, however, only the NetMeeting tool was officially deployed in the CAR team. Auto 1 managers explained that they believed they would need to get permission from European Community authorities to share calendar information, as regulations exist to protect exporting employee data and privacy. This issue deterred the managers at the research site from pursuing the implementation of the calendar as part of this project, although local managers strongly encouraged individual use of MS Outlook unofficially. Furthermore, an awareness tool implementation was planned to follow the NetMeeting training and deployment. Yet, at the conclusion of the study, the research site had not expressed an interest in deploying the awareness tool.

In conjunction with the site management team, we identified a subgroup for early adoption of NetMeeting within the participant team. These individuals were selected because their management believed they had an immediate need to collaborate with remote colleagues. We trained 15 team members in two US and two European locations. The one-to-one training involved a 15 minute introduction followed by a 30 minute guided use of NetMeeting in an actual desktop conferencing session.

5. Follow-up survey analysis and results

5.1. Level of adoption

From the responses to the baseline survey, the mean level of motivation to adopt new collaboration tools was high, at 7.94 (s.d. = 1.27) (on a scale from 1 to 10, where 10 indicated most likely to adopt, and 1 indicated least likely to adopt). 68% of respondents indicated a strong desire to adopt new tools: 64% had a strong desire to adopt an electronic calendar, 68% had a strong desire to adopt a presence tool, and 71% had a strong desire to adopt a desktop conferencing tool.

At the conclusion of the study, adoption and use of new collaboration tools was higher for some tools than others: 36% of the respondents reported some level of NetMeeting use, with 6%, regular use; 97% of the respondents reported some level of shared calendar use, with 82%, regular use; and 36% of the respondents reported some level of presence awareness tools, with 12% regular use. NetMeeting use was slightly higher than the proportion of team members trained (25%), but did not achieve widespread usage as we had hoped. Adoption of tools supporting the transition between synchronous and asynchronous communication, even without specific training programs, were as high (awareness tools) or higher (electronic calendar).

Yet, 50% of respondents agreed that NetMeeting had an impact on the CAR team's work, with most agreeing that it had improved the efficiency and speed of the design process. Of these respondents, 82% agreed that the efficiency of the design process had improved, whereas 59% and 47% agreed that the speed and quality (respectively) of the design process had improved. Thus, half the team perceived the synchronous tool as affecting the team's functioning, in particular, the efficiency of the design process.

5.2. Changes in coordination and performance

Table 2 compares participants' responses to coordination and delay items before and after the NetMeeting deployment (baseline vs. follow-up). The table indicates the frequency of participants agreeing with statements regarding coordination with CAR team members, as well as the frequency of participants experiencing numerous and lengthy delays.

In the baseline and follow-up responses, CAR team members reported greater difficulty in scheduling common meeting times with remote workers than with collocated workers - however, this difference was smaller in the follow-up survey responses. In the baseline and follow-up responses, CAR team members reported greater difficulty in finding co-workers at remote sites compared to their local site - but again, this difference was smaller in the follow-up responses. Finally, in the baseline and follow-up responses, CAR team members reported receiving more timely information about changes in plans at their local site compared to remote sites - with increases in the timeliness of information at local and remote sites in the follow-up responses. In all, it seems that small improvements in coordination occurred among remote team members following implementation of the collaboration tools.

Table 2: Frequency of participants experiencing coordination and delay difficulties

Items	Baseline (n=33)		Follow-up (n=34)	
	Local	Remote	Local	Remote
Coordination				
Difficult scheduling common meeting times	18%	48%	17%	40%
Difficult finding co-workers	24%	38%	23%	28%
Receive timely information about changes in plans	54%	28%	63%	40%
Delay				
High frequency of delays (+4 in previous month)	50%	42%	41%	36%
High average length of delay (one to several days)	48%	90%	61%	95%

Participants indicated experiencing delays in work involving both local and remote co-workers. In both surveys, a greater percentage of respondents reported a high frequency of delays involving local co-workers. The percentage of respondents reporting high frequency delays decreased for both local (9%) and remote (6%) co-workers. However, the percentage of respondents reporting a high average length of delay increased following collaborative tool implementation, though more for local than remote co-workers. Thus, participants were experiencing fewer delays, though of somewhat greater duration, at the conclusion of the study.

6. Discussion

Our motivation in conducting this study was to understand the impact of collaborative tools on the performance of geographically-distributed work teams. The significance of this research area is highlighted by the growing globalization of work, that requires an increase in coordinated activity across dispersed sites and employees [14, 15, 28]. Specifically, in the manufacturing sector, it is becoming common practice for engineers from different backgrounds and at different locations to combine their efforts to produce novel products [3]. Our strategy to assess the effects of these macro-scale changes was a detailed examination of a geographically-distributed engineering team. Through a variety of mechanisms, the CAR team did experience a significant increase in use of collaborative tools over the year-long period of our study, and that use led to a number of critical insights, which we discuss below.

6.1. The role of collaboration tools

6.1.1. Tool adoption. We were most interested in levels of adoption and use of the recommended collaborative tools, and the relationship between collaborative tool use and any changes in team performance and effectiveness, based on comparison of baseline and follow-up survey measures. To place this effort in context with respect to our main tool intervention of NetMeeting, there are only two published studies on NetMeeting in the literature [18, 6]. In the case of Mark et al. [18], the study focused on room-to-room use of NetMeeting in an engineering design setting within an aerospace manufacturing organization, primarily as an adjunct to audio conferences. Data were gathered on four teams over a period of three months. In the case of Finholt et al. [6], the study focused on targeted dyads of remote users doing software engineering within a telecommunications organization, again, covering a period of three months. Our study extends the nascent research on NetMeeting as a collaborative tool by examining the effect on team outcomes following the intervention, and by probing adoption issues in an organizational setting.

We concentrated NetMeeting training on fifteen members of the CAR team judged, by their management, to have the greatest need for NetMeeting features. This strategy succeeded in exposing NetMeeting to a significant fraction of the CAR engineers (about 1/3). By the end of the study, shared calendar use was ubiquitous in the CAR team. Adoption of presence awareness tools was much lower, with a small number of team members (12%) regularly using presence awareness tools.

A critical question is why was the calendar tool adopted so much more broadly than NetMeeting and the presence awareness tool. A key factor is that in response to our summary of baseline and requirements data, the lead managers within the CAR team made a decision to recommend use of the shared calendar tool. However, NetMeeting was also endorsed strongly by management. We believe an additional factor in the differential adoption rates was that the number of engineers who benefited from the relatively specialized capabilities of NetMeeting or presence awareness tools was much smaller than the number who benefited from the relatively generic capabilities of the shared calendar tool. That is, scheduling is a more universal need. In contrast, a desktop conferencing tool appeals mainly to those workers who must collaborate with distant colleagues in real-time, as when viewing a common drawing or document.

Our interview data support these conclusions. For instance, one US engineer conducted regular intensive collaborative work with a colleague in a European site that required rapid feedback. During the period after the NetMeeting training, this individual reported weekly meetings using NetMeeting - and that these meetings were critical in the resolution of key design problems. In comparison, one manager of the CAR team observed that most of their work with EU colleagues was concentrated on a manufacturing site that had very poor network connectivity. Restricted access to collaborative tools between 1/3 of the team and a key remote team member could explain the low overall adoption rates of NetMeeting.

6.1.2. Impact on coordination and delay. Thus, with ubiquitous adoption of the electronic calendar, and moderate adoption rates of the awareness and desktop conferencing tools, we expected to find changes in the nature of the team's work. We found some reductions in coordination difficulties and frequency of delay at the conclusion of the study, especially those due to remote co-workers. It is possible that the electronic calendar and presence awareness tools offered team members information as to their co-workers' availability and location, facilitating finding team members and scheduling meetings. This finding may support Olson and Olson's [25] suggestion that awareness tools are valuable in managing the transition from synchronous to asynchronous work inherent in distributed teamwork.

To a lesser extent, we also found that desktop conferencing contributed to improved synchronous interactions in the CAR team. Half the team perceived a collective impact of NetMeeting use on the manufacturing design process. Those reporting a change in the team's design process noted that the primary impact was on the efficiency and speed, with a smaller impact on quality of the process. This finding suggests that NetMeeting use reduced some of the difficulties indicated in the baseline interviews, such as interruptions in mid-conversation to email or fax attachments with drawings. Furthermore, it offers modest support for desktop conferencing as a means for facilitating remote synchronous work for teams with visual or graphical information needs [9, 22, 33].

6.2. Techniques for assessment and evaluation

This study provides an opportunity to assess and evaluate collaborative tool interventions that could be generalized to other field settings. In this section, then, we present a summary of the strengths and weaknesses of the research strategy implemented in this study.

Our difficulties in conducting the research reflect the first crucial lesson, in terms of the assessment and evaluation strategy. Doing research in the field, within actual engineering teams, requires enormous cooperation and compromise. For example, we wanted to introduce three collaborative tools - but because of Auto 1 legal and operational concerns - were only allowed to formally introduce NetMeeting. Furthermore, we were subject to change in team membership, which affected both the response rate and level of overlap between in participants in the baseline and follow-up surveys.

Second, we learned that overcoming inertia in organizational settings is very difficult. There seems to be a threshold of benefit assessed by individuals before adoption takes place, which is experienced both in terms of frequency and magnitude of the perceived value added by the candidate tool. We found examples of both assessments in the CAR team. Some adopted the tool, but used it infrequently. Others did not see enough potential frequency of use to justify adopting the tool. For instance, one team member explained that the means available for sharing graphical and test-based information were cumbersome but useful.

A subset of team members with a high potential frequency of interactions did not believe the magnitude of the value added by NetMeeting made it worth adopting. These team members had already found a solution, and were not willing to adopt another similar, but different, solution. Presumably, they did not see a large enough payback in the difference of capabilities provided by the two applications to warrant learning a new tool.

6.3. Practical recommendations

The foremost conclusion of this study is that collaborative tools must meet a specific need to merit the effort of deployment, adoption, and subsequent use. For example, the requirements gathering effort successfully highlighted difficulties experienced by team members when attempting to do cross-site work. At least for some of the engineers, as indicated by adoption and use rates, the set of introduced collaborative tools met the identified needs. For others, the new tools seemingly imposed too great a burden to learn and master, relative to the perceived benefits. Those who found existing solutions satisfactory, or had infrequent interaction with distant colleagues, used NetMeeting infrequently or not at all. Finally, a number of engineers wanted to use the collaborative tools, but couldn't due to infrastructure deficiencies (e.g., poor network connectivity).

In addition, it may be the case that the emphasis on synchronous collaboration (e.g., NetMeeting) was at the expense of tools that support synchronous and asynchronous collaboration. Specifically, formal introduction of asynchronous collaboration technology might have been a useful complement to the synchronous applications, particularly given the small number of overlapping work hours between Europe and the U.S. However, it is unknown whether adoption and use of asynchronous tools would have also been vulnerable to deficiencies in the available network infrastructure.

A second conclusion is that identified targets for change, such as adoption and use of collaborative tools, need adequate support to ensure success. The level of support varies with the complexity and novelty of the proposed tool. For example, a factor in the widespread adoption of shared calendar tools within CAR was certainly familiarity with calendars generally, and the seamless transference of knowledge and practices with paper calendars to online, shared calendars. By contrast, for most CAR engineers, NetMeeting represented a completely new tool, with no analogs from past practice. Therefore, in adopting NM, engineers were asked to master both the tool itself (e.g., operation of the interface, how to establish a connection, how to share an application) and also the choreography of working with a distant colleague via the tool (e.g., trading off control of the mouse, resolving failures and surprises). At least within the CAR team, engineers had much to do just in performing the required aspects of their jobs. While we were strategic in selecting deployment targets for NetMeeting, it was unrealistic to expect that engineers would devote time to instruct colleagues in the use of a sophisticated and complex tool.

In this project, we made a significant investment of research staff time in one-to-one training surrounding the introduction of NetMeeting. The one-to-one training was a success, but probably not conducted on a broad enough scale to create a critical mass of users for this study's timeframe. Less successful was the approach of finding high visibility users to model NetMeeting use, and by example, stimulate wider adoption of the tool. Additionally, some of the users we identified as the most influential adopters of new technology had already taken the initiative by using an alternative, application-sharing tool. This supports the finding from our baseline analysis about the importance of application sharing, but did not help the effort to broaden the base of NetMeeting users.

The foremost practical recommendation for future research on collaborative tools in field settings would be to anticipate competing demands in this type of research. Specifically, adoption of novel tools with accompanying novel practices is not something that unfolds on a time scale consistent with most projects. Therefore, researchers will confront the need to perform some level of "pump priming," that is, there has to be some level of collaborative tool adoption and use to produce behavior and outcomes that can be used to evaluate the impact of collaborative tools. Realistic determination of resources required to produce broad use, is difficult. In this study, for example, we robustly documented the enthusiastic need for features contained in tools like NetMeeting, yet for various reasons, stimulating sufficient levels of use remained a great labor (one-on-one training, follow up visits, and on-going encouragement of use), which came at the expense of further research documentation and investigation.

In conclusion, the goals of this study were to inform both practice (selecting and implementing a tool to aid in remote collaboration in a global engineering manufacturing setting) and research (assessing the coordination and performance outcomes following implementation). Our study contributes to theory by partially supporting the need for a visual desktop conferencing tool in engineering, and the reduction of some coordination and performance problems concomitant with tool use. From the practitioner's perspective, we experienced moderate success with 1/3 of the team adopting NetMeeting following our intervention. The primary lesson derived from this study, relevant to both practitioners and researchers in this field, is that general need drives collaborative tool adoption in organizational settings to a greater extent than specific need (e.g., the success of the unofficial calendar deployment compared to the official NetMeeting deployment). Furthermore, field studies must acknowledge the role of organizational constraints and competing demands on participants, such that collaborative tool intervention meets their needs above and beyond the cost of learning to use a new tool.

7. References

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